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ABSTRACT

The act of exemplary teaching requires the orchestration of subject matter knowledge and pedagogical knowledge with pedagogical content knowledge. If this last component is not sufficiently present, then we may be quite efficient in presenting students with rote information. If this last component is sufficiently present (and carried out well), then students are afforded the opportunity to construct meaning from symbols and images in a manner that allows them to "see" (like a connoisseur) and sort out the underlying relationships that represent the "character of the subject." As science educators strive to find the proper balance, reform efforts encourage increased collaboration between subject matter specialists and Colleges of Education. This paper points to a fundamental tension that typically exists between Colleges of Education and Arts and Sciences, and suggests that each college has historically different ontological, epistemological, and methodological commitments (different paradigms). Such community differences inherent among content-specific disciplines and between colleges, which are deeply entrenched in historical paradigm commitments, reveal the oversimplification of science teacher education reform mandates that stress true interdisciplinary (and transdisciplinary) collaboration. (Contains 39 references.) (Author)

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Dancing with Maggots and Saints: Past and Future Visions for Subject Matter Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge in Science Teacher Education Reform

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The act of exemplary teaching requires the orchestration of subject matter knowledge and pedagogical knowledge with pedagogical content knowledge. If this last component is not sufficiently present, then we may be quite efficient in presenting students with rote information. If this last component is sufficiently present (and carried out well), then students are afforded the opportunity to construct meaning from symbols and images in a manner that allows them to "see" (like a connoisseur) and sort out the underlying relationships that represent the "character of the subject." As science educators strive to find the proper balance, reform efforts encourage increased collaboration between subject matter specialists and Colleges of Education. This paper points to a fundamental tension that typically exists between Colleges of Education and Arts & Sciences, and suggests that each college has historically different ontological, epistemological, and methodological commitments (different paradigms). Such community differences inherent among content-specific disciplines and between colleges, which are deeply entrenched in historical paradigm commitments, reveal the oversimplification of science teacher education reform mandates that stress true interdisciplinary (and transdisciplinary) collaboration.

Dancing with Maggots and Saints: Past and Future Visions for Subject Matter Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge in Science Teacher Education Reform

Introduction

Are you not mad, my friend? What time o' the' moon is't?

Have not you maggots in your brain? (Fletcher, 1620)

Historically, having maggots in your brain was an appealing notion. Fanciful dance tunes of the 1700's by such titles as "Cary's Maggots" and "Barker's Maggots" celebrated whimsical, footloose, and fancy-free character. The phrase, "When the maggot bites" quite literally suggested one who was swept away with capricious and fickle thoughts. Folklore suggested that if the maggot's bite was hexagonal then poetry would consume that person; if circular – then eloquence; if conical – politics. But there is an academic distinction between being a visionary and simply having visions, just as there is a fine line between being whimsical or imaginative and being "mad as a hatter" -- the absence of level-headed thinking. (It is of historical interest to note that during this same time period mercurous nitrate was used to make felt for hats and its poisonous effects produced a dance of an unstable rhythm—Saint Vitus' Dance.)

One can only speculate that the shape of the maggot's bite for educational reform is probably triangular -- albeit dog-eared around the edges. I suggest this only because a centerpiece of educational reform (at least within the circles of teacher education) has been largely a tripartite structure with the anchoring points being teachers' subject matter knowledge (SMK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK). While the idea of a tripartite structure that seems to capture the fundamental attributes of an entity is certainly not new (one is reminded of Plato's three parts of the soul (reason, appetites, and spirit (thumos) or Freud's notion of personality (id, ego, and superego), Shulman (1986a; 1986b; 1987,) was certainly a seminal visionary and instrumental in advancing the importance and distinction among SMK, PK, and PCK (see

also Shulman and Sparks (1992)). Shulman viewed these domains of knowledge as separate but interacting. Assuming that many teacher educators would assent to the claim that this tripartite structure, while not the whole ball of wax, does constitute a large share of the attributes behind being a(n) "exemplary," "model," or "effective teacher," we may then proceed to consider the normative role it plays as part of the reform movement in general, and teacher education in particular.

It should be noted that the reduction of an entity (teacher) or activity (teaching) to principle components may rather be like factor-analyzing the creativity and passion behind Picasso's "Guernica." It may be done, but it no doubt loses something in the representation. Likewise, I believe it may be a misnomer to discuss the role of Subject Matter Knowledge of teachers in the absence of the other two constituent components. Having said that, and to establish a common reference point in this dialogue, Subject Matter Knowledge refers to a teacher's quantity, quality, and organization of information, conceptualizations, and underlying constructs in their major area of study (e.g. science, social studies, mathematics, language arts, etc.). Each major area of study may have many interrelated fields of specialization (e.g. biology, international politics, algebra, journalism, etc.). The ways one can represent SMK within each major area of study may differ widely. Pedagogical Knowledge pertains to a teacher's knowledge of generic instructional variables such as classroom management, pacing, questioning strategies, handling of routines and transitions, and the like. Pedagogical Content Knowledge represents a teacher's ability to convey the underlying details and constructs in their field of specialization in a manner that makes it accessible to their students. While it may not take a leap of imagination to presuppose that the ability to translate complex ideas into concepts that students can grasp requires a threshold of SMK and PK, Kennedy (1998) points out that the intuitive connections among these three anchoring points have not been adequately treated in the research.

A Sampling of Research Literature in Subject Matter Knowledge

It comes to no surprise to those who perform reviews of empirical investigations that methodological choices of design lead to varying findings and interpretations of the data. Furthermore, how one conceptualizes an operational meaning for SMK varies among studies (e.g., understanding the nature of science, conceptual understanding of selected topics or themes). In an excellent analysis of the literature, Lederman and Gess-Newsome (1992) examined quantitative and qualitative investigations while distinguishing between direct forms of assessments (i.e. direct classroom observations) and indirect forms (i.e., self-report tasks that required participants to describe how they prepare for instruction). For example, of seven studies that utilized direct observation of teachers, four suggested evidence supporting the assumption that a teacher's SMK affected his or her instructional approach (Brickhouse, 1989; Dobey & Schafer, 1984; Roth, Anderson, & Smith, 1987; Smith & Neale, 1989) while three provided contrary findings (Duschl & Wright, 1989; Lederman & Zeidler, 1987; Zeidler & Lederman, 1989).

It would be wise, however, to hold summary judgments in abeyance until one examines the fine methodological choices among the studies. Dobey & Schafer (1984), Roth, Anderson, and Smith (1987) and Smith & Neale, (1989) examined settings which involved preservice or inservice teachers. Five additional investigations reviewed by Lederman and Gess-Newsome (1992) which did not utilize direct classroom observation methods produced results supporting the influence of subject matter knowledge upon planning or instructional practice (Baxter, Richert, & Saylor, 1985; Carlsen, 1989; Hashweh, 1986; Clermont & Krajcik, 1989; Krajcik & Layman, 1989). Hence, one is left to ponder the legitimacy of the intuitive assumption that SMK influences classroom practice. It would appear to be the case that there is no evidence that warrants the position that direct transfer of actual classroom teacher beliefs affect their pedagogical behaviors in the classroom. More recent research by Gess-Newsome and Lederman (1995) confirms

this position, while making clear that inservice and preservice programs need not abandon attention to the important relationships among SMK, PK, and PCK contained in Shulman's (1986a; 1986b; 1987) model; rather that teacher education in all its forms (preservice, novice teacher experiences, inservice) needs to be proactive in providing opportunities for reflective practice, and we should not assume that enhanced SMK is isomorphic with exemplary instructional practices. In fact, there is research which suggests that instruction (the *act* of teaching) influences SMK more than SMK influences instruction (Gess-Newsome & Lederman, 1992; Gess-Newsome & Lederman, 1993; Gess-Newsome, 1995; Hauslein, Good, & Cummins, 1992).

The admittedly brief review of studies above is culled predominantly from the research literature in science education. This begs the question that the intuitive (but probably false) relationship among one's SMK, PK, and PCK still exists in fields other than science. I am tempted to argue that this assumption is probably not well-founded in other disciplines, and it might be fallacious reasoning to assume that the interactions of these factors are somehow unique to one discipline. This is not to say that SMK and PCK are not peculiar to different disciplines; instead, the interaction of all SMK, PK, and PCK as a result of real-life settings where teachers face a plethora of administrative obstacles (top-down classroom decisions that impact selection of curriculum materials, scheduling that determines how periods and student experiences are arranged and organized, ratio of students to teachers, availability of resources, performance assessment exams, etc.) does not favor one content discipline over another. After a cursory review of the literature from non-science disciplines, the brute fact (my perception) is that the research on this topic in other areas is either far spottier than that in science education or ill-defined. For example, a sampling of studies from Mathematics Education (Fuller, 1997), English Education (Stengel, 1997), Second Language Instruction (Barnett, 1990), Social Studies Education (Galvez-Martin, 1997) suggests that these areas suffer from many of the same maladies as some of the research found in science education (indirect methods of

observation, self report measures, preservice teachers or inservice teachers not observed in real-life settings). I invite the reader from these other disciplines to study this important topic in more detail. For the time being, I will stick to my claim that the findings from the science education literature have something to say about the connections among SMK, PK, and PCK.

Constructivism, Paradigm Shifts, and Browbeating: What Then, Is the Relevance of SMK, PK, and PCK?

The reader may be inclined to think, given the above review, that the relevance of SMK, PK, and PCK to teacher education and larger reform issues is a moot issue at best or a non-issue at worst. Nothing I have presented would be sufficient to make that fallacious conclusion. On the contrary, I will argue that we should not throw out the baby with the bath water – perhaps the bath water simply needs changing. Although much of the educational research continues to commit Type III errors (asking the wrong questions) (Kirk & Miller, 1986), works from unwarranted assumptions, or suffers from ill-defined constructs embedded in questionable methodological designs, the instrumental role that this tripartite structure potentially plays in educational reform must not be disregarded.

Enter THE sticky wicket. To fully appreciate the role that SMK, PK, and PCK can play in education reform, one must be a "connoisseur" of constructivism in Eisner's (1991) sense of the word. Although constructivism has also suffered a schizophrenic fate worse than Sybyl (Good (1991) points to 15 adjectives used in the literature to describe an array of constructivist camps in which one may stake a claim), its fundamental tenets hold a sense of primacy that are necessary for one to *act* as a connoisseur in educational reform and fully appreciate the qualities associated with the personal and social construction of knowledge (Zeidler, 1997). Assuming that an individual teacher educator has developed a belief system consistent with constructivism, the overarching concern is the extent to which the larger institutional or educational context (other colleagues in an

articulated program, the administration, the public schools at-large, etc.) nurtures visions within that paradigm. This condition is often neglected in research on reform in teacher education. Latour (1987) refers to the role of beliefs with respect to different social institutions as "sociologics" or constructed entities that allow for multiple pathways that lead to multiple social realities. This view stands in stark contrast to "traditional" organizations that typically require top-down driven standardization of curriculum and practices common to many colleges and public schools. What is required on the part of traditional programs (or educators) is the willingness to begin to reconceptualize one aspect of a paradigm. This approach would be consistent with Laudan's (1984) reticulated model for partial, piecemeal change to *either* one's ontological, epistemological, or methodological commitments (another tripartite structure that forms the anchors for a paradigm). Note that this model differs from Kuhn's (1970) view of a paradigm shift in which theory change (core beliefs within a paradigm) would correspond to a change in *all* ontological, epistemological, and methodological commitments – rather like switching a light switch. This necessary condition will be revisited later in the paper. For now, assuming the reader has been sufficiently brow-beaten, let us return to understanding the relevance of SMK, PK, and PCK to teacher education.

It may be inferred from the research previously cited that a teacher's SMK may be a necessary but insufficient condition for the transfer of central ideas, precepts, tenets, and the like for a given discipline to be made accessible to his or her students. While keen PK (good generic classroom management tools, questioning techniques, etc.) ensures that the core ideas (SMK) can be presented efficiently, the act of exemplary teaching requires the orchestration of these two with PCK. If this last component is not sufficiently present, then we may be quite efficient in presenting students with rote information. If this last component *is* sufficiently present (and carried out well), students are afforded the opportunity to construct meaning from symbols and images in a manner that allows them

to "see" (like a connoisseur) and sort out the underlying relationships that represent the "character of the subject" (Kennedy, 1998).

Three examples help to throw light on the above claims. Consider first the following passage cited by Gould (1995) where Charles Darwin used a comparison of the biblical image of the "tree of life" to convey taxonomic hierarchies among organisms:

> The affinities of all the beings of the same class have sometimes been represented as a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have tried to overmaster other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs; and this connection of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. (pp.451-452)

One can see from this historic example that SMK is being conveyed by Darwin in a manner that allows those in his time (who might resist reform and change for a variety of institutional reasons) to draw on familiar symbolism to construct and appreciate this new concept. Consider also a more contemporary and familiar scenario in teacher education:

> College students might be able to recite knowledge of atom, for instance, by noting that atoms are typically 1 or 2 Å in radius, and that an angstrom is equal to 10^{-8} cm. Being able to recite such facts can yield a high test score, a high grade point average, and a strong diploma. However, being able to recite such facts does not ensure that the student (soon-to-be

> teacher) could explain to younger students how big an atom is—to explain it in a way that could be understood by, say high school students (Kennedy, 1998, p.257).

Kennedy (1998) contrasts this with a parsimonious metaphor used by Richard Feyman (1963/1995, p.5) in his lectures on physics: "If an apple is magnified to the size of the earth, then the atoms in the apple are approximately the size of the original apple." This use of metaphor depends on a good grasp of scientific content (SMK), strategic timing (PK), and allowing students to construct personal meaning and conceptual understanding. (PCK). Consider one final example in which Gould (1996) dispels the myth that *Homo sapiens* are the necessary and predictable result of evolution because we are endowed with (perceived) intrinsic superiority. In this case, the presentation of SMK is coupled with a clear, literary style of writing that allows the novice reader to temporally order information and construct episodic meaning.

> If one small and odd lineage of fishes had not evolved fins capable of bearing weight on land (though evolved for different reasons in lakes and seas), terrestrial vertebrates would never have arisen. If a large extraterrestrial object—the ultimate random bolt from the blue -- had not triggered the extinction of dinosaurs 65 million years ago, mammals would still be small creatures, confined to the nooks and crannies of a dinosaur's world, and incapable of evolving the larger size that brains big enough for self-consciousness require. If a small and tenuous population of protohumans had not survived a hundred slings and arrows of outrageous fortune (and potential extinction) on the savannas of Africa, then *Homo sapiens* would never have emerged to spread throughout the globe. We are glorious accidents of an unpredictable process with no drive to complexity, not the expected results of evolutionary principles that

yearn to produce a creature capable of understanding the mode of its own necessary construction. (p. 216)

There are surely many devices to draw upon to fully employ PCK. Richardson (1990) discusses several literary and narrative tropes a teacher or researcher could use to help the student or reader build connections and construct meaning from conceptual themes. One can recognize the utilization of synecdoche (part represents a whole) in Darwin's "tree of life" example. Metaphor used at a conceptual level to represent scale and structure was certainly present in Feyman's lecture. A special case of the cultural story (in this case -- *Homo sapiens*) is eloquently presented by Gould. And while many other tropes abound (myth, fable, comedy, painting, dance, cultural and collective stories, etc.), they must be crafted by the perceptive teacher and delivered in a manner that is comprehensible and relevant to the students. One wonders if this craft can be "taught" by teacher education programs, let alone content specialists from colleges outside a college of education who lack an appreciable understanding of cognition, metacognition, learning processes, misconceptions, reasoning structures and fallacies, growth, and development.

Can there be A Seamless Relationship between Subject Matter Specialists and Teacher Educators?

Unlikely. At the risk of sounding like a curmudgeon, my experience in higher education to date tells me that while relationships are possible between, say Colleges of Education (teacher educators) and Colleges of Arts and Science (subject matter specialists), *seamless* relationships are rare. Furthermore, the problem with seamless relationship is one never knows where it will tear apart. And while I fail to deliver "hard data" in this article, I will offer a synthetic argument to illustrate the central problem that exists for reform-minded individuals who undertake such relationships and invite the reader to rewind and replay their own experiences whenever joint ventures (and adventures) were implemented among these two communities. Pillaging two concepts from sociology allows for the construction of a metaphor that captures the fundamental

tension that typically exists between Colleges of Education and Arts & Science. The concepts are *Gemeinschaft* and *Gesellschaft* presented by Ferdinand Tönnies in *Community and Society* (1887/1963). True, Tönnies descriptions of Europe's Middle Ages and its transformation into the "modernization" of European society might at first blush seem out of sorts with contemporary social institutions of higher education (a modern form of community), but the salient features of said concepts might help to understand how deeply rooted that tension may be, and why a seamless relationship between subject matter specialists and teacher educators may be nearly a phantom image.

Communities based on *Gemeinschaft* shared common work or calling, kinship or neighborhood, spirit or mind – hence common beliefs, virtue, and morality spontaneously arise. Thus, an artisan or professional creates and produces without calculation of units of time and compensation. Conversely, *Gesellschaft* (reflecting the transition into European "modern" society) represented process, as well as a state of affairs in which individuals associations were guided by a network of legal and moral relations that were not naturally produced, but imposed with calculation to aggregate citizens into a type of polis based on instrumental economic utility. "...In *Gemeinschaft* they (individuals) remain essentially united in spite of all separating factors, whereas in *Gesellschaft* they are essentially separated in spite of all uniting factors" (Nisbet, 1966, p.75).

Admittedly we do not live in feudal times, but subject matter specialists (who typically reside in Colleges of Arts and Sciences) and teacher educators (who are typically housed in Colleges of Education), have been known to feud. These two colleges represent in very significant ways two different communities, each based on their own conceptualization of *Gemeinschaft* (I realize that there may exist many sub communities within a given college but for the sake of example I will treat each college as an homogeneous entity). Many times (and especially for the sake of reform goals), imperfect unions are imposed upon these two communities that lead to a forced state of *Gesellschaft*. We remain fundamentally separated in spite of all the uniting reform factors

that attempt to link us together from external mandates and political (i.e., politically correct) pressures. Each college has historically different ontological, epistemological, and methodological commitments; hence different paradigms are deeply steeped in traditions that stand in contrast to one another. Yes, relationships between two, distinct homogenous traditions are possible, but the heterogeneous, mutated offspring produced are a constant reminder of the tension that exists among these historically different communities. Each community is rather isomorphic in its institutional traditions and requiring between-group variation to over come within-group variation presents unique challenges to those who wish to forge partnerships that cut across disciplines.

Summary and Implications: Terra Incognita

The presentation above leads to several analytic or inferential claims that may be culled from the literature. It is my contention that these claims are important for teacher educators and subject-matter specialists to become familiar with for forging new relationships in unfamiliar territory. Perhaps these claims may also provide fodder for further empirical or conceptual investigations. These are summarized below:

• Exemplary teaching practices necessarily include the interaction of SMK, PK, and PCK.

• The nature of the interaction among SMK, PK, and PCK may be counter-intuitive to our notions of teaching. Increased emphasis on SMK does not necessarily affect instruction; rather, it is more likely that the act of teaching influences SMK.

• A constructivist philosophy is required to fully "appreciate" the interplay among SMK, PK, and PCK and their role in teaching and learning.

• Ontological, epistemological, or methodological commitments (pieces of a paradigm) need to be held in common before seamless relationships between subject matter specialists and teacher educators may begin to be forged.

• Community differences inherent among content-specific disciplines and between colleges are deeply entrenched in historical paradigm commitments that reveal the

oversimplification of reform mandates that stress true interdisciplinary (and transdisciplinary) collaboration.

If the shape of the maggot's bite for educational reform is indeed triangular, then the roles of SMK, PK, and PCK will continue to hold center stage as the walls that divide disciplines are chipped away. It is, however, noteworthy that the image of having "maggots on the brain" has evolved from flights of fancy to something of more somber overtones in recent history (recall many more recent colloquial expressions like "rats in the garret" and "bats in the belfry"). With renewed aims and goals in educational reform, we engage in the equivalent of national revival meetings at annual conferences and dance to new ideologies, saints, and sinners. But let us be prudent in our choice of whims, ideologies, and dance steps. While reform visionaries have their visions of interdisciplinary and transdisciplinary collaboration, we must acknowledge that there remains a fine line between the deliberate movements of whimsical, celebratory dances of reform and the involuntary jerks of a nervous disorder where Saint Vitus meets reform agendas. More attention must be paid to the central tensions that exist between and among paradigms of thought within university communities lest we uncontrollably dance to new rhythms.

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